REMARKS UPON THE MECHANICAL DEVELOPMENT OF SEX IN ANIMAL LIFE.

BY THE LATE PROFESSOR S. L. SCHENCK, OF VIENNA.

In the following article, consideration will be given to a number of facts calculated to lead to further discoveries within the sphere of our theory, viz., the dependence of sexual difference upon outward influences. I will begin by observing that the reader will soon gain the conviction that, among the many theories brought forward since the earliest times upon the subject of influence on the formation of sex in the ovum, one alone can lay claim to accuracy and validity, that, namely, which is intimately connected with the theory of nutritious and organic exchange. From that standpoint I have attempted to solve this question.

To the theory which I have here undertaken to discuss, opposition is general, while attacks upon it are continuous, both from qualified and unqualified judges of the matter. This question, raised by me, has called forth a complete literature of its own since the publication of my work, and this has had the effect of strengthening and confirming my views on many points.

In natural science, it is certain that a cell cannot dispense with nutrition and organic exchange in the performance of its natural functions, which manifest themselves in the most varied ways. The necessary conditions for these must be supplied. In favorable and normal circumstances, the cell will fulfil its natural career, and also provide for the preservation of its kind.

If we, however, in any way change the conditions of nutrition, and the exterior circumstances connected with these, corresponding effects will necessarily manifest themselves. This is true not only of such cells as are independent living organisms, but also of all cells existing in a cellular form for the support of an individual. The conditions of existence for these latter cells, as also for the

life of the whole organism which they make up, obviously cannot be carried out without the nutrition and organic exchange of the same. Each of the elementary organisms constituting the whole must perform its organic exchange as it is supplied, in order to multiply, to maintain its life and its species. This increase is only rendered possible *by each individual cell being supported by the whole parent organism, a constituent part of which it forms, if it is to contribute to the support of the whole.*

When, then, should the ovum cell, proceeding from a metamorphosed epithelial cell in the animal organism of a metazoön, be independent of the influence of the parent organism in whose ovary it is developed? The different forms which an epithelial cell of the ovary passes through, until it arrives at the permanent shape of an ovum, ready for impregnation, are an evidence *that the changes and metamorphoses taking place in the ovum require nutriment to assist in their structure.*

This is certainly not contained in the ovum alone, the epithelial cell on the surface of the ovary, nor is it so constituted as to dispense with assistance from the parent.

Now, it is seen that the mature ova, ready for development, in the case of a large number of animals, may be removed from the parent after impregnation, and develop to perfection by artificial breeding or incubation. It is quite otherwise with the ova before they attain maturity. Here they are entirely dependent on the parent organism to which they belong. On these their completion depends: they possess the same chemical constituents as these, and receive them from the parent during their development. Only by means of the nutrition and organic exchange of the parent can the ovum contained be influenced in the most diverse ways during its *development before impregnation.*

It is self-evident that, through this influence, the special characteristics of the ovum may be developed or varied to a certain degree. This point is also worthy of notice, for the reason that by these means certain changes may be introduced in the ovum, calculated to produce various essential alterations in the offspring of certain classes of animals.

The hereditary nature of the characteristics of different individuals in a normal state, and the deviation from these normal conditions in cases of disease, are equally qualified to give ground

to the assertion that not only does chemical and physiological action take place in the cells, producing changes therein, but that also the parent animal, whose morphological constituents consist of these cells, must have an important influence on their metamorphoses, mode of life and pathological formation.

Now the ovum protoplasm and its nucleus also contain its capabilities in other directions, so that we find in it everything prepared that is necessary to development.

By the chemical analysis of the ova of various animals, it is shown that the chemical elements necessary to their structure, which are present in the developed animal, are also contained in the ovum before impregnation. These elements are probably not received into the ovum direct from the exterior world of the parent organism, but only by the intermediation of the parent animal, whose most important task is doubtless to nourish and preserve the ovum. All these processes must take place before impregnation, and during the period when the germ is undergoing development, from its first origin until it is sufficiently matured for impregnation. The chemical elements of the mature ova of different animals have often been analyzed by scientists. A complete literature exists upon this branch of experiment. The chemical changes and synthetical processes of different substances in the ovum after impregnation are accompanied by complicated morphological changes. Hitherto we have gained but little insight into these.

The elements of the human ovum, which is not so accessible to chemical research on account of its microscopic size, have not been investigated so thoroughly as those of other classes of vertebrata possessing larger ova.

The bases of the chemical and physiological processes are formed in the ovum. These seem to take place regularly in the different ova, as the processes after impregnation, as well as the phenomena of maturation, repeat themselves more or less constantly, and are maintained to a certain extent in various succeeding generations. Here, however, there are a number of processes to be noticed, which are manifested by visible changes, and form the object of direct observation. The effects of these are such as lead to the development of permanent animal forms, with corresponding signs. They include the phenomena of the ontogenetic and coenogenetic characteristics of organic individuals during de-

velopment. In addition to these visible processes, which are recognizable by morphological signs, there also occur within the ovum changes of a physiological nature, the knowledge of which is still imperfect and insufficiently studied.

So, for example, are formed the functional power of the heart's action, of the breathing apparatus, of the intestinal canal, of the central and peripheral nerve system, of motility, etc. In all these processes, besides a number of anatomical signs to be observed, leading to development of the permanent forms, there are certain other constantly recurring actions in the histological elements and the organs composed of these, the study of which is at present impossible.

To this class of phenomena also belong the origin and completion of the difference of sex in the human ovum and in that of animals. In these changes taking place in the ovum, it is impossible to detect any morphological or physiological sign, by means of which it might be determined with certainty in the case of the unimpregnated ovum, in its early stages of development, whether it be male or female.

It may, however, be said with certainty that this phenomenon must be considered as inherited, and that a fundamental cause must precede this heredity. The heredity of sex appears to be connected with the heredity of other physiological qualities. With the preservation of the latter quality in the offspring, it also happens that the one or the other sex is formed in the ovum.

Its appearance at this time does not seem to be an independent formation of the genital regions alone. The sex may also be affected by the influence shown by other important points in the development and maturation of the ovum. In the question of the heredity of sex, the heredity of other forms of action, by which the sex may be influenced in either direction in families (through inheritance), must not be left unconsidered. Those qualities of the parent which affect the sex of an ovum, such as nutrition and organic exchange, appear to be necessarily hereditary, in order to produce an effect in the formation of sex by heredity. It is impossible to leave out of question the active influence of the parent animal. The ovum coincides in all conditions of nutrition with the parent, whether the former be in the earliest stage of development or in a state of maturity. Even after impregnation,

the dependence of the various processes of development upon the parent is not to be denied.

Some ova remain in contact with the stroma, and obtain what is necessary to their support directly and continuously from the parent during the embryo existence. Others have gained a certain provision from the stroma, which is employed during the first period after their separation from the parent, until they are able to procure the materials for nutrition from their surroundings outside the parent animal. In both cases the parent originally provides the substratum for the formation of all the parts and organs composing the new organism.

On examination of the various assertions recently made on the subject of influencing the development of sex, it will be found that in most cases one fact is especially prominent, arguing that it is possible to combat and successfully overcome all the different casual moments. According to the theories hitherto prevalent, these causes may be explained in the most diverse ways. It is, however, certain that the many existing theories may be partly or entirely disproved. Only the theory founded on the nutrition of the parent individual may claim to have been confirmed by many undeniable facts. Those who most hotly oppose this theory are still forced by the facts hitherto published, to allow that nutrition is a means toward the development of a particular sex, if not for all species of animals, yet for a certain class. The significance of nutrition and organic exchange in the discussion of this question is always of the highest importance to the formation of sex. Any one who has the opportunity of studying the conditions of organic exchange in the parent and obtaining the result in figures, will soon be able to remark differences in the totals of these columns worthy of attention. It will be found that these show a greater capacity for the consumption of nitrogenous substances in connection with the male sex, than in the case of those ova which develop into female individuals. Such figures concerning the consumption of nitrogenous food are also of importance so far as they are of assistance in the determination of important questions concerning the early period of gestation, the solution of which is very desirable.

A number of observations are here briefly adduced, which may assist in confirming the principles of our theory on "Influence on

the Relative Proportions of the Sexes," and the dependence of these on nutrition and organic exchange.

On the announcement of my publication, a treatise by Dr. Ludwig Cohn, in Königsberg, appeared, in which this question was discussed from the standpoint of biological and statistical experience. He seeks to disprove modern ideas, and takes a negative view of every branch of the subject.

This principle of negation cannot, however, be observed in the question of the nutrition of the embryo. He is here compelled to take into consideration the observations on plants first made by Knight, namely, that those grown in a well-manured soil produce a superfluity of female forms.

As regards many animals of inferior classes, we are in a position to testify to facts, proving that there is an undoubted influence on the formation of sex by means of nutrition.

Firstly, the experiments of Landois on caterpillars of the *Vanessa urticæ* genus bear witness to this. He succeeded in producing male or female specimens at will by a first abundant and afterward scanty scheme of nutrition.

The effects of nutrition on the sex of bees has been noticed constantly. Larvæ placed in queens' cells and well nourished become queens, while those hatched in workers' cells and badly nourished become sexually imperfect workers.

In the case of stag beetles, various rudimentary deformities are found. This phenomenon is strikingly noticeable in circumstances of insufficient nutriment during the larva period.

In the case of scanty nutrition, it is usually the males that preponderate and are imperfectly formed.

The eggs of the phylloxera also show that a larger or smaller quantity of the food which serves to nourish and preserve the embryo during the embryonal period, also affects the sex of the same. Females are produced from the larger eggs laid in autumn, and males from the smaller ones. But, in many cases in the animal kingdom, males and females may be distinguished in the earliest embryo form, in the so-called cellular period. Many farmers assert that with fowls' eggs they can deduce the sex which the egg will produce by its outward shape. Thury also mentions the observation of O. Bourit, according to which, in the case of many singing birds, the last-laid egg is said to be conspicuously smaller and during incubation to develop into a male.

Observations have also been noted in the case of the higher animals, showing that scanty nutrition is favorable to the development of males.

Ploss asserts that the proportion of male births rises and falls with the price of food. According to this author, more boys are born in the Kingdom of Saxony in times of agricultural depression. In Paris, in the years from 1841 to 1850, the fluctuating price of grain is said to have been noticeable in the same manner. In reference to these phenomena, Rolph characterizes males as a "hunger generation." In explanation of this fact, Alexander von Padberg makes the following remarks: "Bad times, bad living and food do not affect men and women in like degree. Women have more patience and endurance than men. One reason of this is that the latter have, generally speaking, more needs than women. It seems that, in circumstances of scanty nutrition, the preservation of the individual is provided for, and not that of the race. Men suffer also more in times of want, both bodily and mentally, than the more abstemious women, who are less dependent on food. Hence, the greater influence of the latter on procreative action, and (according to the theory of *crossed sexual heredity*) more male births. This theory of crossed sexual heredity has long been known. Oken and Buffon were acquainted with it. It was treated with much penetration by the mental specialist Richarz, of Enderich, near Bonn, and considerably strengthened by Janke, by a minute account of the proceedings of the American farmer Fiquet, and by the experiments of Düsing.

A remarkable preponderance of boys in the country, in comparison with the inhabitants of towns, and the same among mountaineers, has been often proved (Ploss, Conradi, Giron, Horn). The conditions of nutrition, and especially the organic exchange of the parent individual, have an influence on the formation of sex, not only among the lower animals, but also in the case of the higher species, and also of man. The fact is well known to huntsmen that, in years of plentiful forage, females predominate in the hunting districts, especially among mammalia; this has been vouched for constantly.

In eggs parthogenetically developed, among crustaceans as well as insects, the influence of nutrition on the determination of sex may be seen in a remarkable manner. Not the nutrition alone, but certain circumstances connected with it, are especially

worthy of notice. *Artemisia salina,* a small salt-water crab, is influenced by an alteration in the quantity of salt in the water, so that in consequence of dilution it produces a preponderance of male offspring.

Maupas, and later Nussbaum, occupied themselves with the rearing of *Hydatina.* It was found by experiments that more males were produced by keeping the animalculæ in cold water, but when this was heated to from twenty-four to twenty-six degrees, Centigrade, a numerous generation of females was the result.

In the reports of the *Monde Médical* (Vol. VIII., No. 2, Paris, 1898), mention is made of a contribution by Le Dantec to the *Comptes Rendus.* In the course of his studies on heredity, the above-mentioned author came to the conclusion that the sexual differentiation of two *Plastidæ* of the same genus could not be caused by any difference in their chemical composition, and that it must, therefore, arise from their molecular dissimilarity.

By the use of Pasteur's nutritious fluid, in which a solution, saturated with pro-tartrate of ammonia, is employed as an aliment, the nutrition has an influence on the *Plastidæ,* particularly in the determination of sex. Hence Le Dantec declared himself ready to adopt the theory formulated by myself.

Mary Treat,[1] of Vineland, New Jersey, called attention to an interesting fact observed by her in the early seventies of last century. In this experiment the determination of sex appeared especially dependent on the supply of food. Hence results were obtained by artificially influencing nutrition. Thirty-four males and one female were produced from a so-called "male" box, in which male specimens of *Papilio asterias* were bred by means of underfeeding. Out of seventy-nine specimens, fed by Mary Treat in the above-mentioned manner, with a view to the production of males, only three females were found, the others proving to be males. An entire exclusion of the female sex was not attained, a fact which coincides, generally speaking, with the experiments of other writers. I am acquainted with similar experiments on silk-worms, among which a large preponderance of males was effected, but it was difficult entirely to prevent the production of females in a single experiment. It appears that the complete exclusion of one sex from a brood very rarely occurs. It is also probable that all these animals have not equal capacities of assimilation, so that

(1 *The Journal of Hygiene and Herald of Health,* Vol. XLVIII, 1898, No 5.)

a difference in the latter may easily occur, inferior nutrition having the same effect on one specimen as abundance on another.

In Koch's Encyclopædia of collected animal medical science, among nine classes of the results of the subjoined experiments, one class is especially prominent, in which the formation of sex in offspring is said to be effected by nutrition, this latter, when superior, being favorable to the production of the female, and, when inferior, to that of the male sex. Young, well-nourished mothers bear proportionately more female children, while those older and not so well nourished have more expectation of male offspring. But it is conceded by Wilkens that, in addition to nutrition, there are other influences at work upon the determination of sex, which may not yet have been considered, and the investigation of which has not yet been made. Hence it occurs that one and the same female generator, in the same conditions of stimulation, does not always generate the same sex.

In Fühlung's *Agricultural Journal* (Leipzig, 1898), various opinions are quoted by Robert Müller on the causes of the relative proportions of the sexes, among which nutrition is mentioned, regarded in the form of abundant or scanty food. But, according to my ideas, nutrition is not to be considered alone, but, in connection with it, the processes of organic exchange, or the employment of the food taken, must be especially studied.

A certain symptom served me as an important guide, namely, the disappearance of sugar from the urine to a mere minimum, or even entirely, so that it cannot be discovered by our present chemical tests, and at the same time the appearance of an increase in the reductive substances, when a male human being is being developed. In these analyses, it is particularly important to ascertain the quantity of albumen assimilated, which can be easily calculated by the amount of nitrogen found in the urine.

The idiosyncrasy of the individual has an influence on the production of a certain sex, hence he has the tendency, through the course of successive lines of descent, to generate particularly one or the other sex.

Lorenz asserts, from his genealogical studies, that entire families appear predestined to the generation of female offspring, and that in some the tendency to male, in others to female, births repeats itself from generation to generation. One also meets with

the tendency of many families to produce always male or always female first-born through long lines of descent.

Generally speaking, it is only possible in the case of reigning families to determine which sex has predominated in succession through a long line of generations. One fact is certain, that it is only in the rarest cases that one sex occurs exclusively, without the presence of the other if only in very small numbers.

In the study of the heredity of sex, in my opinion, the following points must be remarked. It is not to be supposed that in offspring only one class of the progenitors' idiosyncrasies are to be regarded as hereditary. One cannot admit heredity of sex, without almost conceding the heredity, in the individual concerned, of many other anatomical or physiological signs shown during development.

These inherited characteristics are perhaps necessary, as the active principles involved in the determination of sex might not otherwise take effect.

A mutual dependence in the formation of the different physiological functions of the individual during development, appears to be as certain as is the fact that in the post-embryonal existence of an adult, the various vital physiological functions of an organism must act in a definite connection toward each other. If features, color of the hair and eyes, shape of the hands, and other peculiarities are transmitted to descendants by heredity, why should not the capacity for nutrition and organic exchange be looked upon as hereditary also? In such a case, might not the assimilating powers of the individuals in question be inherited through many generations?

The time will come when numbers alone will not be considered in the genealogy of different families, but after obtaining a sufficient number of *data,* it will be possible to observe other conditions affecting these cases, such as the manner of nutrition and organic exchange. The heredity of these latter appears to be a fact worthy of notice with regard to the determination of sex.

It is not, however, to be denied that there may be many other additional influences, of which we have hitherto no exact knowledge. It may be seen from statistical reports that no case is at present known in which one sex alone is constantly found in a line of successive generations, but there are many cases known of families in which isolated representatives of the other sex occur here and there.

As I have stated before, there are cases in which the desired result is scarcely attainable by means of outward influences. In experimenting, one meets with cases in which it may be seen by the results of assimilation, even during the experiment, that there is no hope of successfully influencing the formation of sex by means of nourishment. In these latter cases a power of resistance with regard to the assimilation of food appears to be shown, by which it is impossible to obtain a sufficiently large assimilation of albumen, such as is necessary to obtain a male by arbitrarily influencing the sex.

It is still to be added that a number of writers have been occupied with this question of late years since my publication, among whom are Giovanni Canestrino, A. Gevidelli, L. Weill, of Strasburg; K. Fukii, in Tokio, who also established the influence of nutrition on plants; Professor Dangeard, of Poitiers, and many other scientists.

At the conclusion of my article I venture to introduce, as a curiosity, a quotation made by Michael Stephanides,[1] of Mételin, in which the geographer Strabo gives an account of the influence of nutrition on the formation of sex in human beings. Concerning the arbitrary determination of sex by means of dieting, among the Germanic tribes from India, Strabo writes: "Thus by means of their medical science, they were able to produce either male or female generation, effecting this either by drugs or by the use of certain kinds of food."

[1] (*Revue Scientifique*, Paris, July 16th, 1898.)

S. L. SCHENCK.